Data in ENSDF from Nuclear Reactions

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Reactions with γ-ray data:

1. Heavy-ion fusion reactions leading to high-spin structures.
   (Most common type of data in present literature. Consult XUNDL database.)
2. In-beam γ-ray studies with light ions: (p, n γ); (d, p γ); (α, n γ), *etc*.
3. Capture γ-ray data: (n, γ) with thermal or higher energy neutrons; (p, γ), *etc*.
4. Coulomb excitation, generally with heavy ions.
5. Inelastic scattering: (n, n' γ), (p, p' γ), (γ, γ'), *etc*.
6. Resonance data: (p, γ); (n, γ); (α, γ), *etc*.

Quantities:

Eγ, relative Iγ, branching ratios, multipolarities, mixing ratios, conversion coefficients (if needed). (Supporting data: γ(θ), γ(lin pol) coefficients A_2, A_4, POL; γγ(θ): DCO) ratios; measured conversion coefficients, measured sub-shell ratios, *etc*.)

Level energies; Jπ's; measured lifetimes; measured g factors; band assignments.

Reactions with particle detection (no γ-rays):

1. Single-particle transfer reactions (stripping/pickup):
   (d, p); (p, d), (^{3}He, d), (pol d, p), *etc*.
2. Two-, three- or multi-particle transfer reactions: (p, t), (t, p), (α, d), (α, p), *etc*.
3. Charge-exchange reactions: (t, ^{3}He), (^{3}He, t), (p, n), *etc*.
4. Inelastic scattering reactions: (p, p'); (n, n'); (d, d'), (α, α'), (e, e'), *etc*.
5. Coulomb excitation with the detection of scattered particles.
6. Resonance data: (p, p); (n, n), (p, n); (p, α), *etc*.

Quantities:

Excitation energies, Jπ's (deduced from a reaction), L-transfers, S-factors, Transition probabilities (BEL values), deformation parameters, total and/or partial width parameters, measured cross sections.

Gamma-ray Data:

In heavy-ion fusion reactions, data are often available from several different reactions. It is more practical to generate a separate data set for each reaction, especially, when Iγ's and/or branching ratios are independently available from each reaction. Data sets for light-ion reactions such as (p, xnγ), (d, xnγ), (α, xnγ) should be kept separate from those for heavy-ion reactions. Avoid combining reactions such as (d, p) and (d, pγ) in one data set. Data sets for resonance data (*e.g.*, (p, γ), (n, γ), *etc*.) should preferably be given for all resonances, but especially when the primary transitions from such resonances have an impact on the energy/Jπ of the bound states.

Eγ's:
When experimentally measured Eγ's are not available (quite common in low mass nuclides *e.g.*, in A=21-44 region), the values should be deduced from level-energy differences with recoil removed. No uncertainty should be quoted. Avoid giving assumed uncertainties if the authors do not quote any. Quite often the authors give a general statement about range of uncertainties, *e.g.*, 0.1-0.5 keV. In such cases, one could either assign the highest number in the range as the uncertainty for each Eγ or scaled uncertainties within the quoted range based on γ-ray intensities. When no uncertainties are quoted, a common uncertainty should be assigned (temporarily) for least-squares adjustment procedures (*e.g.*, running GTOL code). GTOL code has default value of 1 keV, which may be an overestimate for some of the quoted Eγ's. One may assign a common uncertainty of 0.3 keV for Eγ's quoted to a tenth of a keV. (GTOL code allows assigning common uncertainty through a control record at the head of a dataset).

Iγ's:
When authors give relative Iγ's as well as branching ratios, both sets of data should be given, if branching ratios are deduced independently from coincidence data. One set (preferably branching ratios) could be given under comments or in some sort of tabular manner. For relative Iγ's, there is no need to renormalize authors' intensities to 100 for the most intense γ ray. Uncertainties should be quoted only when explicitly given by the authors as separate values or some sort of a range. For prompt and delayed intensities (*e.g.*, in case of isomers), either generate independent data sets or give one set of intensities under comments. Relative γ-intensity data from different reactions or at different bombarding energies should not be combined in the Iγ record. Use comment records for giving alternative set of intensity data.

Multipolarity assignments:
It is quite common, especially in high-spin papers, that definitive (*i.e.* no parentheses) multipolarities are assigned to all the γ rays in a table even when supporting data are available for only a few of these. One reason for such assignments is that some analyses codes such as RADWARE require the multipolarity assignment for each γ ray and the authors tend to keep those in the papers. In ENSDF data sets, the multipolarity should be given only if the paper quotes supporting data: *e.g.*, γ(θ), γγ(θ)(DCO), γ(linear pol), conversion coefficient. Note that γ(θ) and γγ(θ)(DCO) data by themselves are parity insensitive. One needs additional arguments such as γ(linear pol), conversion coefficients, upper limits on transition strengths (RUL) for levels of known lifetimes, unambiguous rotational band assignments, *etc*. One should also recall that γ(θ) and γγ(θ)(DCO) data, generally, do not distinguish between ΔJ=2, quadrupole and ΔJ=0, dipole (+small quadrupole) transitions. Usually, one needs to invoke other arguments (*e.g.*, rarity of ΔJ=0 transitions) to prefer the given choice.

Although, it is presently an option to quote supporting data (*e.g.*, A2, A4, Pol, DCO values, conversion coefficients, *etc*.) in ENSDF. It is however, recommended that such data be presented in ENSDF so that it is convenient for a reader to judge the validity of a multipolarity assignment based on actual measurements.

Mixing ratios:
In ENSDF, Krane-Steffen's phase convention (as in PR C2, 724 (1970)) is followed. If the authors have a different phase convention, change it according to those given in Table 1 of an article on phase conventions by M.J. Martin in the 'Procedures Manual'. If two/multiple values are given for a certain transition, with no preference for one of these, then all these values should be given under comments.

Conversion coefficients:
In reaction data sets, the theoretical values as calculated by HSICC code should be given only if necessary for some subsequent calculations.

Level Schemes:
A particular reaction data set should contain only the level scheme and data as given in that reaction. This is particularly important while considering

discrepant level lifetime data or other parameters such as mixing ratios, angular distribution coefficients, *etc*. If some placements or ordering of γ-ray sequences differ significantly from those in adopted level schemes or in more recent papers, then the level scheme presented in the reaction data set should be revised with ample comments, or at least, the discrepancies should be pointed out.

Level Energies:
These should be recalculated based on Eγ's in the data set, using least-squares adjustment code *e.g.*, GTOL. Multiple/uncertain placements may need special attention. One should examine carefully the output of GTOL code for significant deviation in fitted *vs*. experimental Eγ's, especially, those cases where the deviation is larger than 2 × the quoted uncertainty for Eγ.

Spins and parities:
For γ-ray data sets, recommendation is to give 'adopted values', but with comments where Jπ has been determined in that reaction and when 'adopted' value is different from that proposed by the authors. Quite often, in high-spin papers, the assignments given by the authors are just best guesses, based on band associations or γ-ray sequences. Some high-spin analyses codes such as RADWARE seem to need Jπ input for each level. If no supporting data are available, one may put all these assignments under parentheses.

See also guidelines for strong/weak rules for such assignments, including the one just for high-spin data.

Lifetimes and g-factors:
In a reaction data set, these values should be given only when measured in that reaction. Values that differ significantly from those in 'adopted levels' should be pointed out under comments.

Annotations for band assignments:
Annotations for band- or γ-sequence-assignments should be given in terms of band flags and brief band descriptions (configuration, Kπ, *etc*.). One needs to use extra care in labeling these bands when a level may correspond to more than one band or either of two levels may be a member of one band. This occurs when the levels have mixed configurations. Also one needs to indicate band crossings, either by labeling these as separate bands or by ample comments.

Particle reactions:

Data sets such as ‘Coulomb Excitation’ and ‘Inelastic Scattering’ should not be combined into one data set. Also generate separate data sets for reactions such as (p, p’) and (n, n’), single-particle and two-particle transfers, *etc*.

In resonance data, the excitation energy should be given in the level energy Record. Energies of particle resonances (in lab system) and associated parameters (partial/total widths) should be given in relabeled records or on continuation type of (‘2 L’) records.

Jπ’s in particle-transfer reactions:
These assignments should be given only when determined in that particular reaction, *e.g.*, through Ay(θ) measurements in polarized beam experiments. Shell-model orbitals involved and Jπ of the target should be specified under comments at the head of a data set.

S-factors in particle-transfer reactions:
Various definitions are used in the literature, depending on the mass region and other features. Definitions used in a paper should be specified under flagged comments. If values are available from different authors, it may be better to list all these rather than averaging, since optical model-parameters used in the DWBA type of analyses may differ amongst these papers.